JUVENILE PASSAGE PROGRAM: A PLAN FOR ESTIMATING SMOLT TRAVEL TIME & SURVIVAL IN THE SNAKE AND COLUMBIA RIVERS

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EXECUTIVE SUMMARY

A plan for developing a program to evaluate juvenile salmon passage is presented that encompasses the Snake (Lower Granite to McNary Dams), Mid-Columbia (Wells to McNary Dams), and Lower Columbia (McNary to Bonneville Dams) segments of the Snake/Columbia River system. This plan focuses on the use of PIT-tag technology to routinely estimate travel times and reach survival of outmigrating yearling and subyearling Chinook, sockeye, and steelhead during spring and summer months. The proposed program outlines tagging studies that could be implemented in (a) 1992, (b) near term (1993-94). and (c) long term (1995 to the next decade). The evolution of this program over time parallels plans to establish additional PIT-tag detector and slide-gate systems at Little Goose, Lower Monumental, McNary, John Day, and Bonneville Dams. The eventual ability to concurrently estimate travel time and survival of release groups will permit evaluation of travel time-survival-flow relationships and identify possible mortality “hot spots” for remediation.

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INTRODUCTION

Background: Juvenile Passage Program

Travel Time Estimation

Starting in the 1960s. the National Marine Fisheries Service (NMFS) monitored the effects of dam construction in the Snake and Columbia Rivers on the migratory characteristics of juvenile salmon. Numerous studies indicated that the emplacement of dams had impeded the rate of migration for spring emigrants (Ebel and Raymond 1976; Sims et al. 1976, 1977; Raymond 1979). This was a result of the combined effects of the blocking structures (dams), the creation of impoundments, and altered flow patterns. Sims and Ossiander (1981) and Sims et al. (1983) described smolt travel time and flow relationships for yearling chinook and steelhead through the Snake and into the Lower Columbia River. Based on these studies, smolt travel time became a key response indicating the effects of flow levels on downstream migrants. Currently, it is the principal response used by fisheries managers to evaluate water management strategies in the Snake/Columbia River system.

Smolt travel time can be estimated in several ways. In one protocol (I), the median passage date of marked groups is estimated at recovery sites in the mainstream rivers, and the difference between the dates at any two sites is the estimated median travel time. This method was first employed by NMFS and is still used by investigators at the Fish Passage Center (FPC) (Berggen and Filardo 1991). This method is generally applied to freeze-branded hatchery stocks. but it is not restricted to such groups. Estimates derived using this protocol can be subject to considerable bias. The FPC identified this problem in the Mid-Columbia where travel time estimates for some hatchery groups from Rock Island Dam to McNary Dam were calculated as negative one day (FPC 1989). They attributed the observed error to project operations and sampling limitations at Rock Island Dam. It is difficult to assess the extent of similar sources of bias at other sites. Because the travel time estimates are derived from estimates of the passage index distributions at upstream and downstream sites. that assume proportionate spill effectiveness and constant FGE (fish guidance efficiency, a prescribed value for the population estimate), the potential for bias elsewhere is a concern. The need to estimate medians passage dates at two different locations increases the likelihood of measurement error.

In an alternative protocol (II), migrants are captured, Passive Integrated Transponder (PIT) tagged, and released at trap sites or dams on a regular basis. The median travel time of each group is estimated as the elapsed time from the known date/time of release to median passage date at a downstream recovery site. This protocol is preferable to the first in that a median passage date need only be estimated at one site, the downstream recovery site; it is known at the release site. This protocol has been and continues to be used at trap sites upstream from Lower Granite Dam and at Rock Island Dam. The Smolt Monitoring Program (SMP) recognizes the merits of this approach and is expanding its application in 1992 to include Little Goose Dam.

A third protocol (III) involves rereleasing PIT-tagged fish that arrive at sites equipped with PIT-tag detectors and slide-gates. Under this protocol, more detailed information can be collected. Changes in the migration speed of individual fish can be measured repeatedly as they move through the hydro-complex. This type of protocol has not yet been implemented, because fish must be intentionally returned to the river at rerelease sites which does not occur. At this time, Lower Granite Dam and Little Goose Dam are the only dams with this proven technological capability. The Lower Monumental facility is to be evaluated in 1994. One limitation of this protocol is that biological attributes of individual tagged fish cannot readily be ascertained at the rerelease site because fish are not rehandled.

There is evidence that at least two principal mechanisms influence the migratory behavior of certain salmonid species or races; water velocity and the physiological process of smolt development. These factors appear to work in concert to influence the response we observed, smolt travel time. This has been most evident in yearling chinook populations. Necessarily, if regression analyses are used to investigate relationships, measures of all demonstrated and suspected independent variables need to be incorporated. Even so, it may be difficult to isolate effects due to particular independent variables when they exhibit correlated trends over the course of the outmigration as has been observed in some years (Beeman et al. 1990). When direct measures of the independent variables are not available, surrogates have been used by some investigators to capture, or represent, the effects of the actual variable (e.g., residence time upriver from Lower Granite Dam used as a surrogate for degree of smoltification). However, it is often difficult to demonstrate that the surrogate properly characterizes the variable of interest, and this undoubtedly accounts for some of the considerable variability that attends such regression analyses.

Alternatively, it may be advisable, or necessary, to conduct manipulative experiments to isolate the effects associated with a particular factor. Short-term perturbations in the hydrograph, on the order of several days, should produce responses that are discernible within short reaches of river, e.g., within pools. Generally, opportunities for flow manipulation are limited in the Snake during the spring, but may be more reasonable in the summer months. The Mid-Columbia offers improved capabilities to control flows.

The preferred approach is to obtain direct measures of all independent variables to match with each measure of the dependent variable (smolt travel time) or tagged group. It would also be beneficial that measurements be taken on individually coded PIT-tagged fish for later analysis relating the fate of these fish to their individual traits. Furthermore, it is necessary to release tagged groups regularly over the course of the entire outmigration. Daily releases are probably not necessary; rather, releasing discrete groups every few days should suffice. The goal should be to span all prevailing water conditions and population segments of the migration. This is particularly important in the context of Endangered Species Act considerations, since wild summer and spring chinook stocks in the Snake River tend to be the earliest and latest yearling migrants, respectively.

Reach Survival Estimation

The need for improved smolt survival estimates through key reaches of the Snake and Columbia Rivers under current conditions is generally recognized. Estimates of suitable accuracy and precision have been difficult to acquire. Methodologies used by NMFS in the 1960s and 1970s (Raymond 1979, Sims and Ossiander I98 1) have been considered deficient and have not been employed since 1982 (Sims et al. 1983). Even though no measures of variance, or assessments of potential bias, attend these general system survival estimates from the 1970s. they form the basis for quantifying the relationship between smolt survival and river discharge volumes that is broadly applied in the basin. From these generalized estimates, parties have derived indirect estimates of reservoir mortality which, in turn, are expressed as various relationships to flow. These relationships are the foundation of numerous regional fish passage models.

Apart from the general failure to characterize the uncertainty inherent in the data and analyses, there is another fundamental limitation with applying historical survival estimates today--the data were acquired many years ago in a very different river system. Physical structures and facility operations have changed. Bypasses have been installed and regularly redesigned. Spill and water management programs have evolved and been implemented. Biological systems have changed, too. The complement of hatchery and wild salmonids has changed. The population structure of predatory fish has undoubtedly changed over the years, but how and to what extend is unknown. This in itself has obvious implications to reservoir mortality dynamics, yet we cannot quantify them. Thus, even if the historical data were statistically sound, its relevance in today’s ecosystem is questionable.

The opportunities for providing improved smolt survival estimates are being assessed by a Bonneville Power Administration (BPA) sponsored working group. The advent of the PIT-tag system has provided new possibilities for estimating survival both at discrete localized sites (dams), as well as over reaches within the river. In concert, such estimates will serve to quantify the magnitude and identify the location of effects. This will assist in both identifying mechanisms causing mortality and developing effective solutions. The theoretical basis for the estimation procedures has been presented by Burnham et al. (1987) and expanded upon by John Skalski's staff at the University of Washington. Pilot studies to explore the application of these techniques are now feasible.

GOALS OF THE PROPOSED JUVENILE PASSAGE PROGRAM

Goals

The overall goal of this proposed Juvenile Passage Program is to provide improved information regarding the migration speed and survival of smolts through key reaches of the impounded Snake and Columbia Rivers, and identify and assess the factors affecting those responses.

Specific objectives of the program are as follows:

1. Estimate smolt survival probabilities through reaches of the Snake and Columbia Rivers.
2. Improve the resolution and quality of travel time estimates by providing direct measures of individual travel times.
3. Evaluate the relationship between smolt travel times, survival probabilities, and environmental variables that might be influencing outmigration success.
4. Compare responses of wild and hatchery smolt where possible.
5. Identify areas of potential high smolt mortality (i.e., reaches, hydrofacilities, or passage routes within individual facilities) for remediation.
6. Provide parameter estimates of reach survival, hydro-project survival, travel times, and interrelationships with ambient conditions for incorporation in Columbia and Snake River juvenile salmonid passage models.

Existing and developing PIT-tag technologies provides us with a means to address these objectives. There are currently three PIT-tag detection sites in the system: Lower Granite, Little Goose, and McNary Dams. These alone offer improved capabilities that we have not yet fully utilized. In the sections to follow, we suggest a variety of new or expanded activities that could now be implemented, using existing detection sites.

More detectors and slide-gate systems are either being installed or planned for installation through the next decade; these include: McNary Dam (1994-95). Lower Monumental Dam (1993-94), John Day Dam (1994), and finally, a detector at the Bonneville Powerhouses (1995-96). These will provide increasingly improved evaluation capabilities. In the following sections, we indicate what estimation opportunities are possible in the future as the complement of facilities increases. In general, to advance towards achieving the stated objectives, it is necessary to expand the use of tagging/release protocol II (intercepting and PIT-tagging active migrants) in the near term and progress toward emphasizing protocol III (rereleasing tagged fish at slide-gates) over the long term.

Reach-specific survival estimates are central in accomplishing objective 3. The proposed methodology, as described in Dauble et al. (1993). requires the rerelease of PIT-tagged fish at the downstream boundary of the reach of interest, and at least one additional detector (i.e., decoder) downstream from the rerelease site. Rerelease can be accomplished by either bypassing the entire population, as is the case anticipated at John Day Dam or diverting tagged fish from the population-at-large at transportation facilities. PIT-tag slide-gates (i.e., diverters) currently installed at transport dams have limited capabilities in that they cannot in real-time identify and selectively divert specific tags from the entire tagged population. Thus, every PIT-tag detected by the slide-gate has to be returned to the river. NMFS researchers are currently evaluating the feasibility of incorporating features into the system that would permit specific tags to be selected and diverted. This capability would avert potential conflicts with programs that call for the transportation of tagged individuals.

Scope of This Plan

This plan recommends means to acquire improved estimates of smolt travel time or survival for yearling and subyearling chinook salmon, steelhead, and sockeye salmon through impounded sections of the Snake and Columbia Rivers, and clearer resolution of key relationships. Where appropriate, we indicate opportunities to provide separate estimates for wild and hatchery stocks. We treat three geographical areas separately; Snake River (Lower Granite Reservoir to McNary Dam), Mid-Columbia (Wells Dam to McNary Dam), and Lower Columbia river (McNary Dam to Bonneville powerhouses). Within each geographical area proposed, activities are blocked into current (1992), near-term (1993-94). and long-term (1995 into the next decade) periods. Activities designated for execution within each period are projected based on the currently scheduled completion of planned PIT-tag facilities, as presented in the previous section. Slippage of that schedule will necessarily delay implementation of certain activities.

PROPOSED JUVENILE PASSAGE PROGRAM

Snake River Program

The current and anticipated capabilities to estimate travel time and survival probabilities in 1992, the near term (1993-94), and the long term (1995+) are depicted in Figure 1. Anticipated improvements and additions of PIT-tag decoding and slide-gate facilities will result in major improvements in the Juvenile Passage Program for the Snake River in years to come. Locations of travel time (TT), reach survival ($\hat{S}$), and project survival estimation (D) capabilities are depicted in Figure 1 by time frame.

SNAKE RIVER

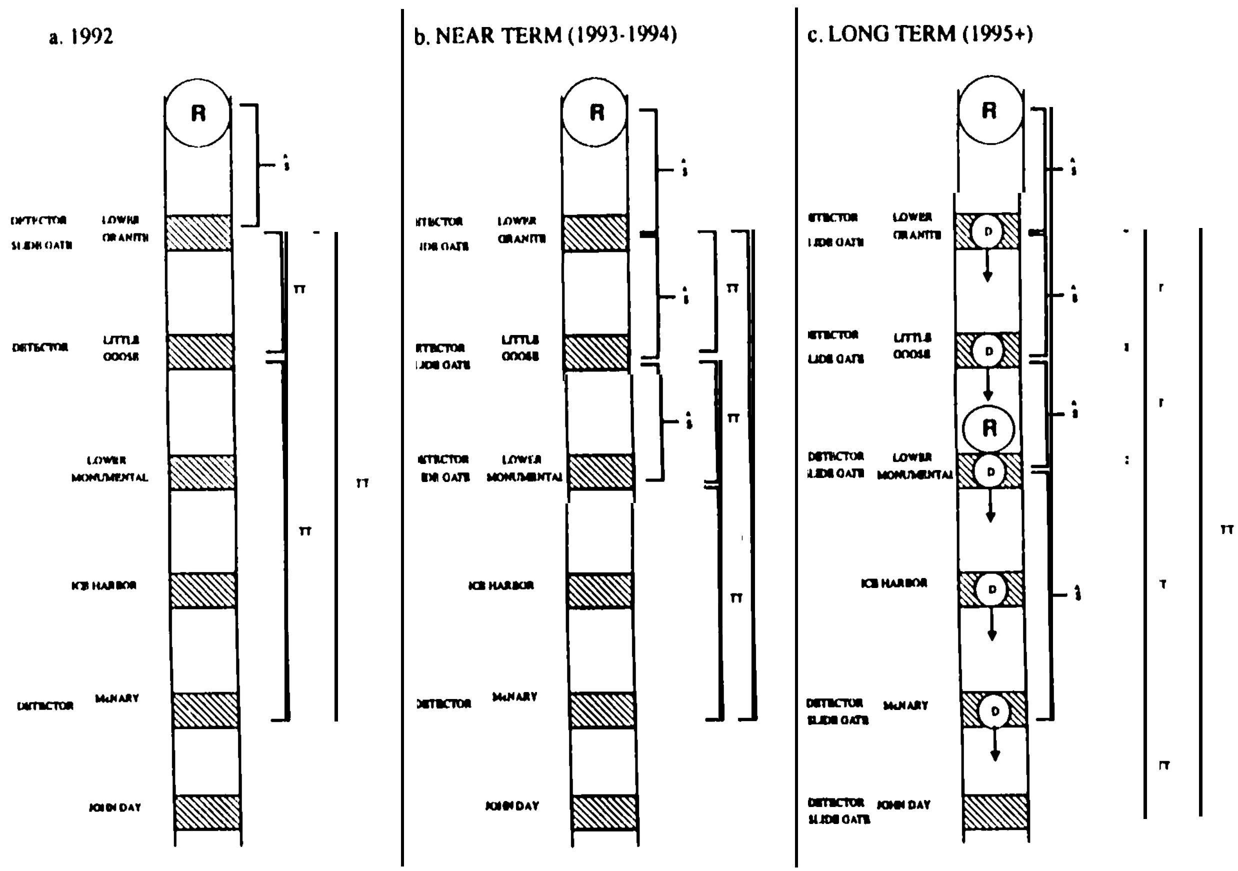

Figure 1. Location of potential estimates of travel time (TT) , reach survival ($\hat{S}$), project survival (D), and PIT-tag detector and slide-gate facilities on the Snake River in (a) 1992, (b) near term (1993-94) and (c) long term (1995+). (R) indicates locations of releases for reach survival estimates.

SnakeRiver: 1992 Program

Reach Survival Estimates: The technological capability exists to conduct a pilot experiment this year; however, implementation is probably not practical at this late date. By using existing detection facilities and rereleasing PIT-tagged fish into the tailrace at Lower Granite Dam, survival could be estimated from any upstream release site through to the tailrace of the dam (Figure la). Yearling chinook and steelhead would be the preferred species, because they are sampled (guided) at high rates at recovery dams and sufficient numbers are available to satisfy release size requirements. Subyearling chinook are poor candidates, because the natural population above the dam is small and would provide few tagged specimens. Also, this race does not guide readily, thus providing limited numbers of tag recoveries.

The proposed rereleased methodology, as described by Dauble et al. (1993). provides survival estimates from any upstream site to the last sampling site where PIT-tagged fish are rereleased and where at least one additional detector is deployed further downstream. Generally, the protocol requires that a sufficient number of PIT-tagged fish be released at any prescribed site(s) upstream from Lower Granite Dam and upon arrival at the dam, be rereleased to the tailrace following detection. Part of **the study** includes quantification of detector-related effects. An important assumption is that detected fish do not incur mortality associated with the detection and rerelease process. Since the detector is contained in the bypass system, it is necessary to quantify detector/bypass-related mortality. It is not problematic, if the mortality is negligible or even moderate. However, if the mortality is appreciable, independent estimates of detector-related mortality will be required for the purpose of correcting the reach survival estimate. We refer the reader to Dauble et al. (1993) for details regarding the estimation procedure and critical assumptions. Ambient river conditions and traits of the PIT-tagged fish would be recorded at the time of the study to ultimately relate to the survival and travel time estimates (Table I). **A** later section in this report details a proposed pilot study for 1993-94.

Travel Time Estimates: The SMP is currently expanding application of protocol II within the Snake drainage. Spring outmigrating yearling chinook and steelhead are being intercepted and tagged at Little Goose Dam and then released into the tailrace. This will provide more direct measures of travel time through a shorter expanse of river from Little Goose Dam to McNary Dam.

1992 Recommendations:

1. Intercept and PIT-tag migrating yearling and subyearling chinook and steelhead at Lower Granite and Little Goose Dams to estimate travel time; this expands the SMP activities.
2. Modify the existing SMP release schedule and sample sixes. Release 200 PIT-tagged fish at Lower Granite Dam to estimate travel time from Lower Granite to Little Goose Dam every two to four days, and release 500 PIT-tagged fish at Little Goose Dam to estimate travel time from Little Goose to McNary Dam.
3. Measure all important variables, biological and environmental (Table 1).
4. Rerelease all PIT-tagged fish detected at Lower Granite Dam, providing additional measures of travel time through reaches below Lower Granite Dam.

Snake River: Near-Term (I 993-94) Program

Reach Survival Estimates: In the near term (1993-94), the slide-gate at Little Goose Dam should be operational. By 1994, slide-gate facilities at Lower Monumental Dam could be fully operational, permitting expanded reach survival studies. With those facilities, PIT-tag releases in the upper Snake can be used to estimate three reach survivals (Figure 1 b); those are as follows:

1. Survival from any upriver release site to the Lower Granite Dam tailrace.
2. Survival from the Lower Granite tailrace to the Little Goose tailrace.

Table 1. Independent variables that can be measured in association with a PIT-tag release.

Independent Variables	
River Factors	Smolt Factors
Temperature Turbidity Flow Water Velocity Day Length	Length Weight Condition Index Disease State Smoltification Index Degree of Descaling Race

3. Survival from the Little Goose tailrace to Lower Monumental tailrace.

The multiple reach survival estimates will help identify the extent of mortality in specific zones for further investigation and remediation.

Travel Time: The multiple PIT-tag detectors and slide-gate facilities will permit travel time estimates in the Little Goose and Lower Monumental Dam pools, from release to Lower Granite Dam, and from Lower Monumental to McNary Dam. In so doing, the composite and incremental travel times in the Snake River can be investigated concurrently with survival estimates to identify zones of potential difficulty and to study changes in outmigration behavior as fish progress through the system.

Near-Term Recommendations:

1. Conduct a replicated pilot study to estimate reach survival.
2. Intercept and PIT-tag migrating yearling and subyearling chinook and steelhead at Lower Granite and Little Goose Dams to provide travel time information, as previously specified for 1992.
3. Measure all important variables on biology of released fish and environmental variables at Lower Granite Dam, Little Goose Dam, and elsewhere to McNary Dam for travel time and reach survival estimation.
4. Operate slide-gate facilities at Lower Granite, Little Goose, and Lower Monumental Dams throughout the spring outmigration and during select periods of summer.

Snake River: Long- Term (I 995 +) Plan

Reach Survival Estimates: The anticipated addition of a slide-gate at McNary Dam and a PIT-tag detector at John Day Dam will ultimately permit estimation of smolt survival from any prescribed release point above Lower Granite Dam to the tailrace of McNary Dam (Figure Ic). The overall survival through the Snake River will be partitioned into survival through four reach segments, including:

1. From release point to tailrace of Lower Granite Dam.
2. Lower Granite tailrace to Little Goose tailrace.
3. From Little Goose tailrace to Lower Monumental tailrace.
4. From Lower Monumental tailrace to McNary tailrace.

Relatively large sample sizes of PIT-tagged fish released above Lower Granite Dam will be necessary for precise estimates of survival in the lower reaches. Alternatively, initial releases at sites below Lower Granite, Little Goose, or Lower Monumental Dams could be performed to obtain estimates of survival in the lower reaches alone. Release studies should be repeated within and between seasons over several years in order to estimate survival under different river conditions and to model survival relationships.

Travel Time Estimates: Corresponding to the reaches where survival can be estimated, travel times also can be estimated concurrently using the same PIT-tag releases and detections (Figure Ic). Travel times can be determined by reach or over the entire Snake River system from above Lower Granite to McNary Dam. By tracking individual fish through the system, the change in travel speed of smolt as they progress downriver can be investigated.

Project **Survival Estimates:** The reach survival estimates discussed above include survival through a pool as well as through the hydroelectric facility. At the hydroelectric facility, the smolt may encounter the bypass, turbine, or spill and experience a different survival rate depending on the route they travel. To partition the overall reach survival between pool and hydro-project, separate survival studies may be initiated to estimate turbine, bypass, or spill mortality using the paired release-recapture methods of Burnham et al. (1987) and/or the relative recovery methods of Ricker (1957), i.e., at McNary Dam.

We anticipate interest in partitioning sources of smolt outmigration mortality after overall smolt survival through the Snake River is characterized. At that time, zones of higher mortality may be identified and remediation undertaken. Although project survival studies will be possible at any dam site indicated in Figure Ic, not all such studies would be practical. Instead, project survival studies may be most important at Lower Granite and Little Goose Dams, because these dams are the first hydrofacilities the smolt encounter during outmigration from the upper Snake River. Studies suggest smolt may incur high levels of project mortality during early outmigration and at the initial facilities encountered. Project survival studies should be replicated under varying operation modes and flow levels to determine how ambient conditions may effect resulting survival probabilities.

Long-Term Recommendations:

1. Intercept and PIT-tag migrating yearling and subyearling chinook and steelhead at Lower Granite, Little Goose, and Lower Monumental Dams to provide travel time information, release numbers, and schedules, as previously described for 1992.
2. Release groups of PIT-tagged fish above Lower Granite and Lower Monumental Dams regularly to estimate reach survival and accompanying travel time. Span the entire outmigration. Studies should continue for several years in order to evaluate alternate flow conditions.
3. Measure all important variables on biology of released fish and environmental variables at Lower Granite and Lower Monumental Dams.
4. Operate slide-gate facilities at all equipped Snake River sites during the spring outmigration and select periods during the summer.
5. Project survival studies should be considered at key hydroelectric facilities such as Lower Granite and Little Goose Dams to partition overall reach survival estimates into reservoir and facility effects.

Mid-Columbia Program

Until slide-gate and detector facilities exist at McNary Dam and at least one additional site such as John Day Dam, reach survival estimates will not be available in the Mid-Columbia (Figure 2). In the interim, travel time estimates based on PIT-tag releases will be the basis for most of the outmigration monitoring in this part of the Columbia-Snake River system.

Mid- Columbia.- I992 Program

Reach Survival Estimates: There are currently no capabilities for estimating **reach survival in the** Mid-Columbia River (Figure 2a). When the slide-gate is operational at McNary Dam, estimates will be possible.

Travel Time Estimates: The SMP is currently PIT-tagging migrant yearling chinook, sockeye, and steelhead at Rock Island Dam. Fish are released below the dam and are recovered at McNary Dam, providing travel time estimates throughout that reach. These efforts should continue and be expanded in accordance with the following recommendations.

1992 Recommendations:

1. To expand the SMP activities, intercept and tag migrating steelhead, sockeye, yearling as well as subyearling chinook at Rock Island. Modify sample size to 500 fish **per** group released every two to four days.
2. Measure all important variables, biological and environmental, for each release group.

MID-COLUMBIA

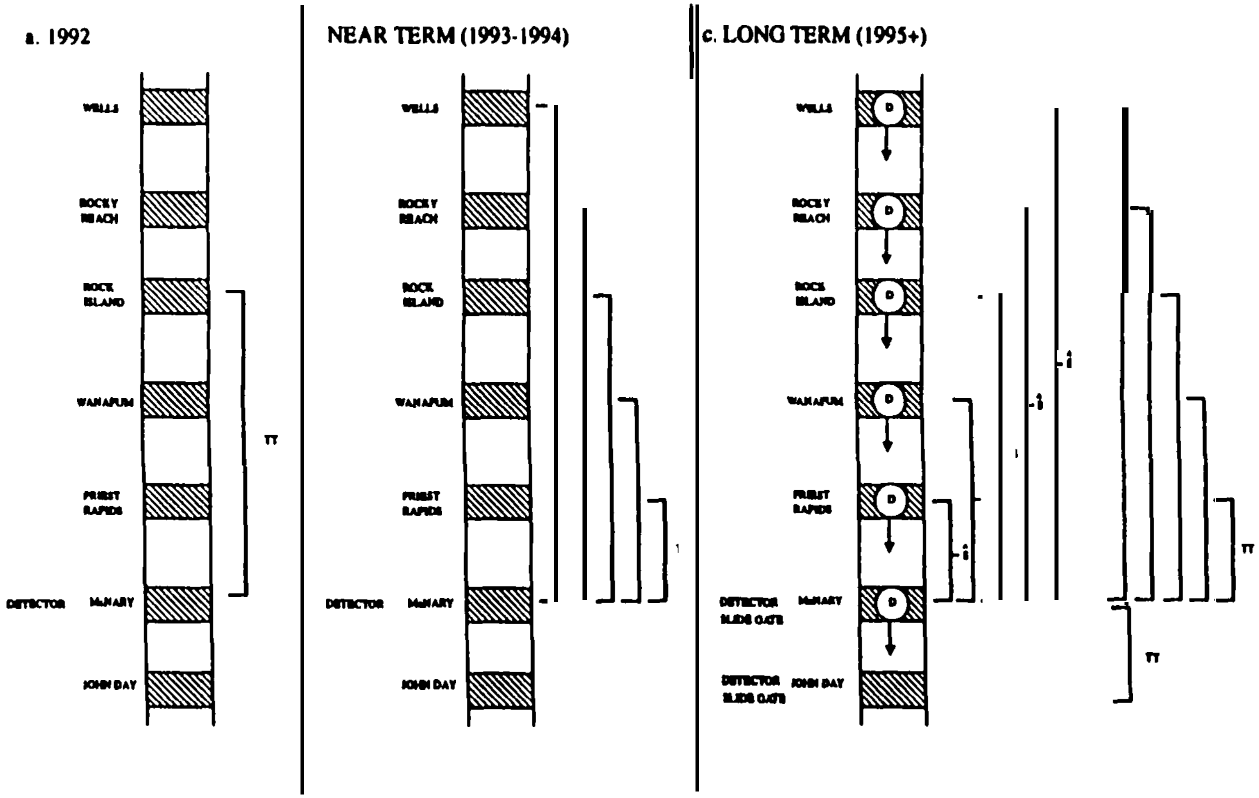

Figure 2. Location of potential estimates of travel time (TT), reach survival $(\hat{S})$, project survival (D), and associated PIT-tag detector and slide-gate facilities in the Mid-Columbia River in (a) 1992, (b) near term (1993-94) and (c) long term (1995 +).

Mid-Columbia= Near-Term (1993-94) Program

Reach Survival Estimates: In the near term, PIT-tag facilities will remain inadequate for estimating reach survival (Figure 2b).

Travel Time Estimates: PIT-tag releases in the Mid-Columbia could be expanded to include estimation of travel times between McNary and upriver sites other than Rock Island Dam (Figure 2b). Although releases could take place at any convenient location in the Mid-Columbia, all travel time estimates would be based on having McNary Dam as the terminal location. Adding a site near Wells Dam would provide travel time estimates over the breadth of the Mid-Columbia.

Near-Term Recommendations:

1. Continue intercepting and PIT-tagging migrating steelhead, sockeye, and yearling chinook, and include subyearling chinook, at Rock Island to estimate travel to McNary.
2. Release groups of PIT-tagged fish approximately every three to four days. Span the entire outmigration.
3. Measure all important variables, biological and environmental, for each release group.

Mid-Columbia= Long-Term (1995+) Program

Travel Time Estimates: PIT-tag program for travel time estimation established in near-term should continue into the future. Plans to estimate travel time should be coordinated with future capabilities to estimate reach survival in the Mid-Columbia.

Reach Survival Estimates: With the eventual addition of slide-gate facilities at McNary Dam and a PIT-tag detector at John Day, reach survival can be estimated in the Mid-Columbia (Figure 2c).

The reach over which survival can be estimated can include any release point but ultimately terminating at the tailrace of the McNary Dam. One or more release sites should be identified in the survival monitoring. These sites could be Rock Island and Wells Dams to encompass the breadth of the Mid-Columbia and to take advantage of releases used in travel time estimation.

Project Survival Estimates: Following initial reach survival studies, estimates of turbine, bypass, or spill mortality rates could be obtained at select sites should concerns arise with regard to mortality “hot spots.” Such project survival studies could be performed using the paired release-recapture methods of Burnham et al. (1987). e.g., at Wells, Rocky Reach, Rock Island, Wanapum, Priest Rapids, or McNary Dam.

Long-Term Recommendations:

1. Establish regular releases of PIT-tagged fish near Wells and Rock Island Dams to routinely estimate travel times and reach survival to McNary Dam. Manipulative experiments of flows may be desirable or warranted.
2. Measure all important variables in biology of released fish and environmental variables at Rock Island and Wells Dams.
3. Operate slide-gate and detector facilities at McNary and John Day Dams throughout the course of the outmigration.
4. Project survival studies should be conducted to distinguish facility from reservoir effects.

Lower Columbia Program

As with the Mid-Columbia, through the near-term (1994) evaluation capabilities are very limited (Figure 3). Major improvements in monitoring will have to wait until establishment of detector and slide-gate facilities at McNary, John Day, and Bonneville Dams (Figure 3).

LOWER COLUMBIA

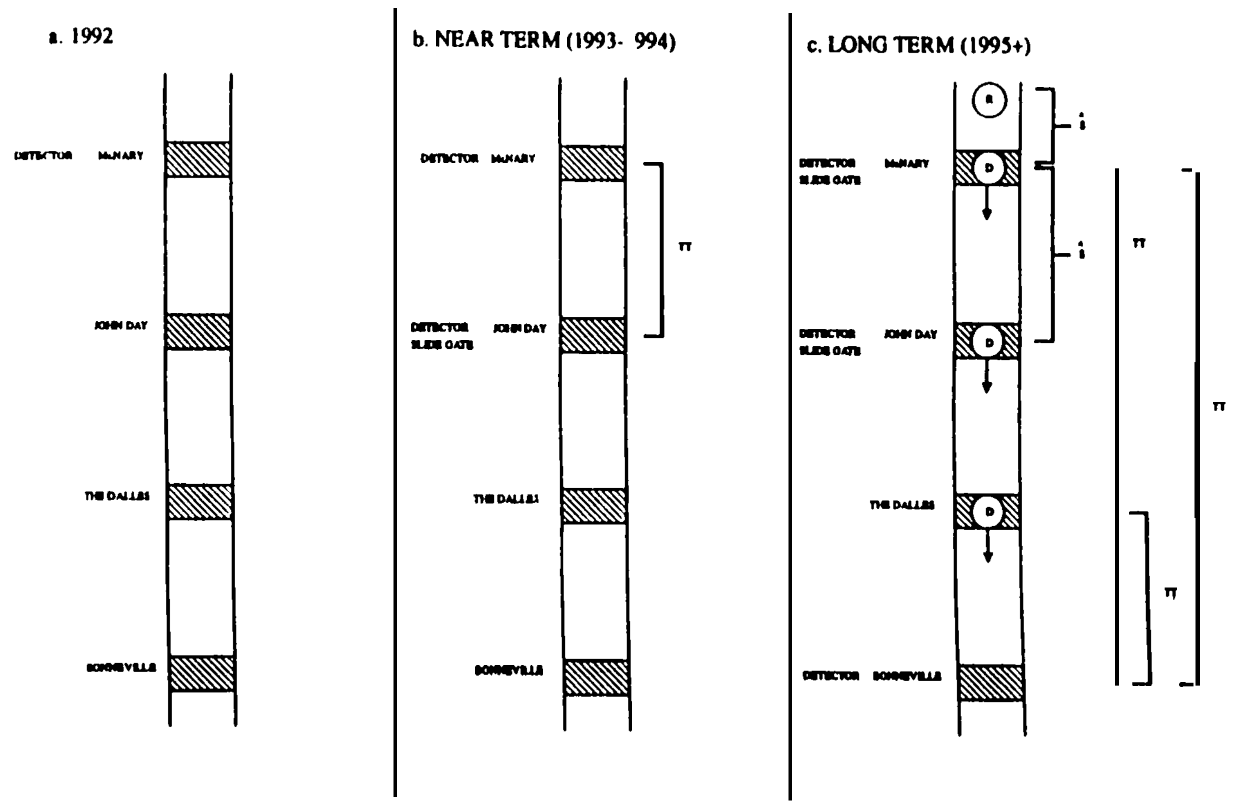

Figure 3. Location of potential estimates of travel time (TT), reach survival $(\hat{S})$, project survival (D), and associated PIT-tag detector and slide-gate facilities in the Lower Columbia River in (a) 1992, (b) near term (1993-94) and (c) long term (1995+). (R) indicates location of releases for reach survival estimates.

Lower-Columbia: 1992 Program

Reach Survival Estimates: There is currently no means to estimate smolt survival through any portion of the Lower Columbia River. However, in the future, with a detector installed in the bypass at John Day Dam and detection at Bonneville Dam, it will be technologically possible to estimate survival through the John Day pool. Pilot studies proposed elsewhere in this plan will provide assessments of the feasibility.

Travel Time Estimates: At this juncture, mark-recovery capabilities in the Lower Columbia River are very limited. Historically, brand release studies at McNary Dam with recoveries at John Day Dam result in extremely low recovery rates, $\leq 1.4\%$ (e.g., 1987: RA-7 F-l; yearling chinook $23/10658 = 0.0022$), and associated poor estimates of travel time. We recommend directing efforts elsewhere until either John Day or Bonneville Dam is equipped with PIT-tag detectors.

1992 Recommendations:

1. Direct efforts elsewhere in the system.

Lower-Columbia: Near- Term (I 993-94) Program

Travel Time Estimates: Installation of a PIT-tag detector bypass facility at John Day Dam by 1994 will permit estimation of travel time between McNary and John Day Dams.

Reach Survival Estimates: Lack of multiple sites with PIT-tag facilities will continue to preclude reach survival estimates in the Lower Columbia.

Near-Term Recommendations:

1. Intercepting and PIT-tagging yearling, subyearling chinook, sockeye, and steelhead at McNary Dam release in tailrace to estimate travel times to John Day Dam.
2. Environmental and biological variables at McNary and John Day Dams should be recorded.

Lower-Columbia: Long- Term (I 995 +) Program

Travel Time Estimates: A major advance in monitoring in the Lower Columbia will occur with the implementation of a slide-gate at McNary Dam, bypass-based detector at John Day Dam, and a detector at Bonneville Dam (Figure 3c). With these additional facilities, travel times can be estimated at release points between McNary and Bonneville Dams. Of primary importance is the estimates of travel time between McNary and Bonneville Dams to monitor the outmigration over the Lower Columbia. Detections at John Day will also permit partitioning travel times between McNary and John Day Dams and between John Day and Bonneville Dams (Figure 3c).

Reach Survival Estimates: In conjunction with PIT-tag releases above McNary to estimate travel time, the reach survival between McNary and John Day Dams can be estimated from the same tagging data (Figure 3c). The concurrent estimation of travel time and survival within the same reach and with the same data will permit investigation of flow-survival-travel time relationships.

Project Survival Estimates: The PIT-tag detector at Bonneville would permit estimation of turbine, bypass, or spill survival probabilities at John Day and The Dalles Dams using the relative recovery method of Ricker (1957) and the Burnham et al. (1987) method at McNary Dam. Selection of hydrofacilities for investigation would depend on the need to evaluate the performance of bypass or spill facilities.

Long-Term Recommendations:

1. Intercept, PIT-tag, and release migrant chinook and steelhead at sites upriver from McNary to estimate survival to McNary Dam and through the McNary-John Day Reach and associated travel times. Conduct studies systematically during each year's outmigration for several years.
2. Operate the detector and slide-gate facilities at McNary and John Day Dams throughout the outmigration.
3. Project survival studies should be performed to distinguish between facility and reservoir effects.

CONSIDERATIONS IN THE SIZES OF PIT-TAG RELEASES

For any type of investigation, the sample size depends on the objectives of the study, type of statistical analysis to be performed, and the precision of estimates or the power of tests of hypotheses that is desired. Three types of data to be collected during the Juvenile Passage Program--that of travel times, reach survival estimates, and survival rates at turbine, bypass, or spill facilities--require separate considerations. Initially, replicated releases will likely be used simply to characterize the natural variability in survival or travel time. Later, studies would most likely be performed to partition that overall variability into components associated with assignable causes (e.g., flow, temperature, season, smolt condition, etc.) and stochastic variability.

Travel Time Estimates

Currently, median travel time is used to characterize the speed of fish passage. Unfortunately, the nonparametric nature of medians makes sample size and sampling precision calculations very difficult. Indeed, the use of median statistics has contributed to the general lack of sample size calculations for estimating travel times on the Snake or Columbia Rivers. The result is that all too often travel time must be calculated using only a few recoveries of tagged fish.

Here we propose a general framework for calculating the precision of medians and associated sample sizes of releases. We also propose an alternative to medians that more readily lends itself to sample size calculations and is more meaningful in quantifying smolt travel speed.

Median Travel Time

Hollander and Wolf (1973) provide a large sample approximation to the confidence limits for a median. The upper and lower 95% confidence intervals for a median are expressed in terms of order statistics (Table 2). As the number of PIT-tag detections increase, the fraction of the range (i.e., maximum-minimum) enclosed by the interval estimate decreases. For example, with 25 detections, the 95% confidence interval for median travel time incorporates the middle 52% of the observed range in travel times. With 200 detections, a 95% confidence interval for the median incorporates only the middle 15% of the observed range in individual travel times. Hence, using medians as a measure for the central tendency mandates precision be expressed as a fraction of the range of order statistics.

The size of release groups of PIT-tagged fish necessary for an anticipated precision in median travel time is a function of the recovery number chosen in Table 3 and the detection rate downriver (Table 2). For example, if the desired precision of the median travel time estimate is a 95% confidence interval that is 25% of the observed range (n = 80, Table 3) and the detection rate at the downriver detection site is 30%, then the required size of the initial release is approximately

$$R = \frac{80}{0.30} \doteq 267 \text{ fish.}$$

Table 2. Order statistics (i.e., ith smallest) associated with a 95% confidence interval for median travel time as a function of the number of fiih detected downriver and percent of **range** the upper and lower confidence bounds (U and L) represent [i.e., $(U-L)/n \cdot 100\%$].

Number of Detections (n)	Order Statistics		% Range $\left(\frac{U-L}{n}\right)$ 100%
	L	U	
25	7th	19th	52.0%
30	9	33	46.7
40	13	39	40.0
50	18		32.0
60	22		30.0
70	27	44	25.7
80	31	50	25.0
90	35	56	[illegible]
100	40	61	[illegible]
150	62	89	18.7
200	86	115	15.0
300	133	168	12.0
400	180		10.5
500	228	[illegible]	9.0

Table 3. Sizes of initial release (R) of PIT-tagged fish as a function of **downriver** detection probability and desired width $\left(\left(\frac{U-L}{R}\right) 100\%\right)$ of a 95% confidence interval for median travel time expressed as a percent of range of order statistics.

	Relative Confidence Interval Width (% of Range)				
Detection Rate	40%	30%	25%	15%	9%
0.10	400	600	800	2000	5000
0.20	200	300	400	1000	2500
0.40		150	200	500	1250
0.60	100	loo	134	334	834
0.80	50	75	100	250	625

We generally recommend the relative width of a 95% confidence interval be less than or equal to 25% of the range.

Harmonic Mean

If the primary interest in estimating travel time is to make inferences to average travel speed (e.g., km/day), then the harmonic mean is the appropriate expression for central tendency (Freund 1988, p. 47). Let $\bar{V}$ denote the true mean travel speed within a reach, then an estimate of the average travel speed of smolt within that reach is

$$\hat{\bar{V}} = \frac{nD}{\sum_{i=1}^{n} t_i} = \frac{D}{\bar{t}}$$

where

D = distance of reach,

t_i = travel time in reach of the ith fish,

n = number of fish detected,

$$\bar{t} = \frac{\sum_{i=1}^{n} t_i}{n}.$$

Furthermore. define precision of the estimate of average travel speed as

$$P\left(\left|\frac{\hat{\bar{V}} - \bar{V}}{\bar{V}}\right| < \epsilon\right) = 1 - \alpha .$$

In other words, we want the relative error in the estimate of average travel speed (i.e., $\left|\frac{\hat{\bar{V}} - \bar{V}}{\bar{V}}\right|$) to be less than ϵ. $(1 - \alpha)100\%$ of the time. For example, we might wish the estimate of average travel speed to be within $\pm 10\%$ of the true value $\bar{V}$, 95% of the time (ϵ = 0.10, α = 0.10).

The required number of PIT-tag detections at the downriver site to have a specified level of precision is a function of α, ϵ, and the coefficient of variation (CV) in travel times among fish (Table 4). To date, we have very little information on the CV of travel times of fiih between facilities because of a lack of release-recapture-rerelease **data.** In the case of Mid-Columbia, travel times for releases from Priest Rapids to McNary Dam are available from PIT-tag data. In the Snake River, PIT-tag travel time data is even more limited. Table 5 reports detection rates, coefficient of variation in travel times among individual fish, species/race, and source of smolt useful in sample size calculations. Sample sizes at point of release *(R)* are calculated according to the approximate formula

$$R = \frac{n}{p} \tag{1}$$

where

n = sample size needed at point of detection based on prespecified level of precision,

p = detection rate of PIT-tagged fish at a downriver recovery site.

Skalski (1992) provides adjusted sample sizes for R that take into account binomial sample error and hence, are more accurate and larger than those computed by Equation (1). Sample sizes of

Table 4. Number of PIT-tag detections (n) required to have a precision of $\pm\epsilon$ for the estimated harmonic mean about the true travel speed, $(1 - \alpha)$ 100% = 95% of the time as a function of the CV in travel time of individual PIT-tagged fish.

CV	n: $\epsilon = 0.10$	n: $\epsilon = 0.20$
20%	16	4
30%	35	9
40%	62	16
60%	140	35
80%	240	62
100%	385	97

Table 5. Information on detection rates and CV in travel times useful in calculating sample sizes of releases for travel time estimation,

Species/Race	Source of Smolt	Reach	Detection Rate	CV (t_i)
Chinook	Active migrants at Priest Rapids	Priest Rapids → McNary	0.602	0.461
Spring Chinook	Active migrants at Little Goose[a]	Little Goose → McNary	0.293	0.285
Spring Chinook	Active migrants at Little Goose	Little Goose → McNary	0.399	1.450

a. Fish were intercepted at Lower Granite Dam and released at Little Goose Dam.

release groups of PIT-tagged fish based on the CV for mean travel time and detection are given in Table 6. For example, approximately 200 PIT-tagged chinook would have had to be released at Priest Rapids (Table 5, detection = 0.602, CV = 0.467) to have a precision of ±0.10, 95% of the time (Table 6, detection = 0.60, CV = 0.40) for the travel time estimate.

Reach Survival Estimates

The report by Dauble et al. (1993) presents sample size calculations for a survival study where the objective is to estimate reach survival from a release point above the Lower Granite pool to the tailrace at Lower Granite Dam. The precision of the reach survival ($\hat{S}$) was defined as

$$P(|\hat{S} - S| < \epsilon) = 1 - a$$

where the absolute error in estimation (i.e, $|\hat{S} - S|$) is to be $< \epsilon$. $(1 - a)$ 100% of the time. Table 7 specifies the detection and mortality conditions used in the sample size calculations. Analyses in that report indicate that the expected precision accompanying a single release group will be quite good. For an example, if 1,500 are released at an upstream site and 60% survive to Lower Granite Dam, using the parameter values indicated in Table 8, the expected precision is ±0.042, 95% of the time. However, this does not reflect natural variability that would be associated with the survival estimate. It is necessary to conduct a replicated study to assess this.

The pilot study would need to be replicated to show the reproducibility of the study and determine the magnitude of the natural variability in reach survival over time. The objective of this study would then be to have a precise estimate of mean reach survival ($\bar{S}$). Defining precision of the replicated study as

$$P(|\hat{\bar{S}} - \bar{S}| < \epsilon) = 1 - a$$

Table 6. Number of PIT-tags that must be released (R) to have a precision of $P\left(\left|\frac{\dot{\bar{v}}-\bar{v}}{\bar{v}}\right| < \epsilon\right) = 1 - \alpha$ for $\epsilon = 0.10$, $\epsilon = 0.20$ and $(1 - \alpha) = 0.95$ about the harmonic **mean** for travel speed when detection rates at the downriver dam are $p = 0.10, 0.20, 0.40, 0.60$, or 0.80 and individual travel times have a CV = 20%, 40%, or 80%.

Detection Rate	$\epsilon = 0.10$			$\epsilon = 0.20$		
	CV = 20%	40%	80%	CV = 20%	40%	80%
0.10	160	620	2460	40	160	620
0.20	80	310	1230	20	80	310
0.40	40	155	615	10	40	155
0.60	27	104	410	7	27	104
0.80	20	78	308	5	20	78

Table 7. Survival terms used in the simulations and conditions under which sample size calculations were performed (Dauble et al. 1992).

Term	**Description**	Value(s) Used in Calculations
S_1	Survival from release to Lower Granite forebay	0.2, **0.6,** 0.9
S_2	Survival from Lower Granite tailrace to Little Goose forebay	0.8
S_3	Survival from Little Goose tailrace to McNary forebay	0.8
S_{spill}	Survival over a spillway	0.98
$S_{turbine}$	Survival through a turbine	0.85
S_{bypass}	Pre-detection survival in bypass	0.98
τ	Post-detection survival in bypass	0.90
Spill passage rate	Probability a fish goes over spillway	**0, 0.2, 0.4,** 0.6
FGE	Fish guidance efficiency	0.5 (Lower Granite) 0.7 (Little Goose and McNary)

Table 8. Predicted precision (ϵ) in reach survival between release point and Lower Granite tailrace for two different release sizes (R) under different spill and survival rates (S) at $(1-\alpha)100\% = 95\%$

S_1	% Spill	ϵ $R = 3000$	ϵ $R = 5000$
0.2	0	0.028	0.019
	20	0.035	0.024
	40	0.046	0.035
	60	0.081	0.056
0.6	0	0.042	0.032
	20	0.060	0.046
	40	0.085	0.059
	60	0.138	0.097
0.9	0	0.050	0.036
	20	0.077	0.055
	40	0.105	0.082
	60	0.152	0.128

we expect the absolute error in estimation (i.e., $|\hat{\bar{S}} - \bar{S}|$) to be less than ϵ, $(1-\alpha)100\%$ of the time. For example, a precision of ± 0.05, 90% of the time specifies $\epsilon = 0.05$, $\alpha = 0.10$. Assuming the natural variation in reach survival is $\sigma_S^2 = 0.0025$ (i.e., $\sigma_S = 0.05$), and detection/rerelease mortality is negligible, the pilot study requires 5 to 7 replicated releases with 1,500 fish each to have a precision of $\epsilon = 0.05$, $1-\alpha = 0.90$, about the mean survival rate. Using these guidelines, we propose the following study be conducted in 1993-43.

Reach Survival to Lower Granite Dam: Pilot Study (1993-94)

We propose a pilot study to estimate reach survival be conducted in 1993 and again in 1994. The objectives of the study are to:

1. Estimate the survival of selected hatchery stocks of spring and summer chinook and steelhead from their accustomed release sites to Lower Granite Dam or other rerelease sites downstream, and define the statistical properties of those estimates.
2. Estimate survival for the wild run-at-large spring/summer chinook (yearlings) and steelhead from trapsites to Lower Granite Dam, or the most downstream rerelease site emplaced on the Snake River.

The purpose of this study is to assess the feasibility of acquiring sound reach survival estimates employing rerelease mark-recovery protocols as described in Burnham et al. (1987) and Dauble et al. (1993) using the PIT-tag detector and slide-gate facilities installed at damsites in the Snake-Columbia River system.

Approach

The approach is to tag experimental groups at a number of hatcheries. Replicates would be released serially over several days and would serve to define variability associated with resultant survival estimates. Realized recovery proportions of rereleased fish at detector sites will be used to determine sample size needs in future investigations. A complementary effort would utilize wild yearling chinook and steelhead intercepted and PIT-tagged at inriver trapsites. Recovery data from this preliminary effort would be used to assess the feasibility of pursuing this strategy in future years.

Objective 1. Estimate survival of hatchery stocks of spring and summer chinook salmon and steelhead from the accustomed release sites to the tailrace of Lower Granite Dam.

Analytical procedures are in accordance with those described by Dauble et al. (1993) as formulated from methods presented in Burnham et al. (1987). One essential condition is that PIT-tagged fish must be rereleased at a minimum of one downstream detection site and that at least one additional detector exist further downstream. Facilities currently in place can satisfy this requirement. Specifically, to estimate survival from any release site to the tailrace of Lower Granite Dam, the slide-gate at that site has to operate to divert experimental fish to the tailrace. If slide-gates are operations at additional sites, i.e., Little Goose and Lower Monumental Dams, reach survival estimates could also be generated in those reaches using these same release groups.

A key assumption of this methodology is that effects associated with the detection and rerelease progress are either negligible or can be quantified, and if appreciable the resultant estimate of detection effects be used to correct the reach survival estimate.

Task 1.1: PIT-Tag experimental groups at representative hatcheries.

Experimental species should include spring and summer chinook salmon and steelhead. Candidate hatcheries include Dworshak, McCall, Lookingglass, Kooskia, and Rapid River. The ability of specific hatcheries to maintain replicate groups or serially release segments from a pooled population (pseudoreplication) will in large part influence site selection.

For each species at each hatchery, a total of approximately 9,000 experimental fish are required. PIT-tagging would occur the fall/winter preceding release. That total number will be blocked into six lots (replicates or pseudoreplicates) of 1,500 fish, employing one of two available strategies. Either each lot will be held in separate rearing raceways/containers/ponds until release, or all 9,000 can be reared in a common environment and blocked into 1 ,500-fish groups at release. One strategy will include variability associated with different rearing containers, while the alternative would not. Facility limitations will be a central consideration in this regard.

Experimental lots could be released in one of two manners, either all in one day or serially over the course of six days (pseudoreplication). The second procedure would lend itself to the situation where all fish were held in a common vessel until release. In any event, to facilitate comparison across hatcheries, it would be preferable that a common rearing and release strategy be employed at all sites. We would recommend the first option of separate raceways and separate releases be performed to obtain an empirical estimate of experimental error.

Task 1.2: Measure effects associated with detection and rerelease at hydroelectric facilities equipped with slide-gates.

A key assumption in the reach survival models is that the detection and rerelease process have no effect on the subsequent survival of these fish. However, fish passing through the detector and slide-gate that are housed in the bypass system may experience a source of mortality associated with this route that is exhibited after the fish are detected and recorded as live. This mortality could be acute or delayed mortality associated with the diversion process or facility-related stress, or because of predation that may target the outfall discharge and occur prior to mixing with tagged fish from other passage routes.

Migrant yearling chinook and steelhead collected at dam sites would be used as experimental animals. Fish would be PIT-tagged and split into two groups. One group would be released just upstream from the slide-gate, perhaps near the separator. The second group would be released in the tailrace, dispersed across the front of the dam and in line with the outfall port.

Each release group would consist of 750 PIT-tagged migrants, all of the same species. For each species (yearling chinook and steelhead), the set of paired release (n = 1,500 total) would occur repeatedly every two to four days, targeting the time frame experimental groups from upriver release sites were arriving at the dam (rerelease site). This period could range from approximately two to four weeks in duration, and require a total of 6,000 to 27,000 fish of each species depending on the frequency of releases and duration of passage of upstream experimental groups.

Task 1.3: Execute data analysis.

Utilize methodologies identified by Dauble et al. (1993). Compare estimates to results reported by other investigators. Report findings and make recommendations regarding strengths and limitations of these procedures.

Objective 2. Estimate survival of wild populations of yearling chinook and steelhead from trapsites in the Lower Salmon River to Lower Granite Dam.

Task 2.1: Intercept and PIT-tag wild run-at-large spring/summer chinook and steelhead.

In order to execute this task, all fish released from hatcheries must bear a readily identifiable mark or tag. Steelhead are so marked with a fin-clip. There are various concerns regarding application of the same type of mark to chinook. However, one alternative may be to universally implant blank, magnetized coded wire tags (CWTs) but without an accompanying adipose clip.

Experimental fish would be collected during the spring outmigration at trapsites on the Salmon and/or Snake River. Wild/natural fish would be distinguished from hatchery stocks by the absence of an identifying marks or tag. Fish would be PIT-tagged at the site and held until either the target of 1,500 fish were achieved, or three days had elapsed, then released. If wild migrant chinook survive at the high rates (85 to 95%). Raymond (1979) previously estimated a sample size of considerably less than 1,500 fish could be adequate in these initial evaluations. This tagging process would continue as long as sufficient numbers of fish were available. Trapsites at Whitebird, Riggins, and Lewiston should be considered, and/or new sites such as at the mouth of the Middle Fork of the Salmon River. A complement of releases from these trapsites would provide survival estimates throughout different sections of the migration corridor.

In addition to survival estimates, corresponding smolt travel time estimates would be produced. This will provide direct measures for wild fish in the drainage, much improved over the only other existing data set for wild chinook, that of NMFS in the early 1970s. Travel time estimates for wild steelhead from Snake and Clearwater traps are currently available as part of SMP activities.

Turbiie, Bypass, or Spill Survival Estimates

The overall mortality during smolt outmigration is a cumulative result of mortality experienced in the upper reaches, reservoirs behind hydroelectric projects, and through the various travel routes through the dams (i.e., turbine, spill, and bypass). Ultimately, there may be a desire to partition the overall mortality rate into the various sources to identify areas of concern and remediation, for instance, reservoir versus dam passage effects. For this reason, turbine, bypass, and spill mortality studies might be conducted at key projects to quantify the extent of mortality associated with the facilities alone.

This information is fundamental in order to derive estimates of reservoir mortality. Existing reservoir mortality estimates, as employed in the Northwest Power Planning Council (NPPC) passage models, were indirectly derived from expansive reach survival estimates by assuming a presumed constant passage mortality occurred at the individual passage routes at each dam. These presumed universally applied passage route mortalities have never actually been measured at a number of damsites. They are “guesstimates” based largely on a study conducted at McNary and Big Cliff Dams in the 1950s (Schoeneman et al. 1961). Actual passage mortality estimates at individual dams are warranted because passage route effects documented at a number of dams are notably different (Schoeneman et al. 1961, Olson et al. 1980, Giorgi and Stenhrenberg 1988, Ledgerwood et al. 1990).

As the number of hydroelectric projects with PIT-tag detectors and slide-gates increase, the complete capture history protocol of Burnham et al. (1987) for paired release-recapture studies will be available for studying turbine mortality, etc. Currently, within-dam mortalities can be studied using paired releases to estimate mortality based on the relative recovery rate method (Ricker 1957) at most sites. The relative recovery method has been successfully used at Bonneville Powerhouse #2 to study turbine and bypass mortality. Success depends on control and treatment releases mixing downriver of the study area.

Should PIT-tag recovery data be available at a number of sites with detectors, but without slide-gates, the first capture history protocol of Burnham et al. (1987) can be used. The exact design of a turbine mortality study will depend on the availability of PIT-tag detectors and slide-gates downriver of the release site. The widely varying availability of PIT-tag detectors and slide-gates below hydroelectric projects precludes specification of all possible alternative study designs in this report.

Instead, the relative recovery method (Ricker 1957), as used at Bonneville Powerhouse #2, will be used to illustrate sample sizes of PIT-tag release groups. The calculations are based on a single pair of tag releases at a hydroelectric facility and with a single detector facility downriver. Sample size calculations are based on a desired precision for the estimate of turbine survival (S) defined as follows

$$P(|\hat{S}-S|<\epsilon) = 1 - a .$$

In other words, we seek sample sizes such that the absolute error in estimation (i.e., $|\hat{S}-S|$) is less than ϵ, (1 - a) 100% of the time. For example, we might desire a precision such that the absolute error is within ±0.05, 95% of the time where

$$P(|\hat{S}-S|<0.05) = 0.95 . \tag{2}$$

The number of PIT-tagged fish that must be released at control (R_C) and treatment (R_T) sites in a turbine mortality, etc., study as a function of $\epsilon = 0.05$, $1 - a = 0.80, 0.90$, and 0.95 at various downriver detection rates is given in Table 9. For example, with a detection rate of 0.40 downstream, release sizes of $R_C = R_T = 4{,}400$ would be necessary to have a precision defined by Equation (2) when turbine mortality is 0.05. The sample sizes **provided above might serve as general guidelines for** conducting release-recapture methods of Burnham et al. (1987). However, specific sample size calculations based on their approach should be performed after specific turbine studies are identified.

The above calculations are based on designing a single study to estimate turbine mortality, etc., at a facility. However, most investigatory studies replicate the tagging study to determine how stable and reproducible are the estimates of mortality. The variance of a replicated survival study can be expressed as

Table 9. Predicted sample sizes ($R_C = R_T$) required at control (R_C) and treatment (R_T) release points to have a precision of $\epsilon = 0.05$; $1 - \alpha = 0.80$, 0.90, or 0.95 when turbine, spill, or bypass mortality is 0.05, 0.10, or 0.15 and recovery rates are 0.20, 0.40, or 0.60.

Mortality Rate	Detection Rate	$(1 - \alpha)$	$R_C = R_T$	$R_C + R_T$
0.05	0.20	0.80	4900	9800
		0.90	8100	16200
		0.95	11500	23000
0.05	0.40	0.80	1900	3800
		0.90	3100	6200
		0.95	4400	8800
0.05	0.60	0.80	900	1800
		0.90	1400	2800
		0.95	2000	4000
0.10	0.20	0.80	4600	9200
		0.90	7600	15200
		0.95	10700	21400
0.10	0.40	0.80	1800	3600
		0.90	2900	5800
		0.95	4100	8200
0.10	0.60	0.80	900	1800
		0.90	1400	2800
		0.95	1900	3800
0.15	0.20	0.80	4300	8600
		0.90	7000	14000
		0.95	9900	19800
0.15	0.40	0.80	1700	3400
		0.90	2700	5400
		0.95	3900	7800
0.15	0.60	0.80	800	1600
		0.90	1300	2600
		0.95	1900	3800

$$Var(\bar{\hat{S}}) = \frac{\sigma_S^2 + \overline{Var(\hat{S}_i \mid S_i)}}{k} \tag{3}$$

where

$Var(\bar{\hat{S}})$ = overall variance for mean survival rate based on replicated survival studies.

σ_S^2 = natural variation in survival among replicate trials,

$\overline{Var(\hat{S}_i \mid S_i)}$ = average sampling error associated with a survival estimate,

k = number of replicate survival studies conducted.

Unfortunately, once again, little or no information is available on the variation in survival rates among replicate trials outside of the Bonneville Powerhouse #2 studies.

In 1988 at Bonneville Powerhouse #2, 12 turbine and bypass survival studies were performed. Dawley et al. (1989) reports a mean squared error (MSE) among replicate estimates of 0.0065 to 0.0082. These estimates of MSE includes measurement error and natural variation in survival, and provides an upper bound on σ_S^2 for these studies. Taking into account sampling error, we used an estimate of σ_S^2 = 0.0025 (σ_S = 0.05) or 0.005625 (σ_S = 0.075) to calculate the number of replicate trials required to satisfy the precision expression

$$P(|\bar{\hat{S}} - \bar{S}| < \epsilon) = 1-a$$

where

$\bar{S}$ = true mean survival rate over replicate studies.

In other words, we want the average estimate $(\bar{S})$ to be with $\pm\epsilon$ ofthetruemean $(\bar{S})$. $(1-\alpha)100\%$ of the time. Table 10 illustrates the numbers of replicate trials and release sizes per trial to have a precision of ± 0.05, 90% of the time. For example, seven replicate trials of $R_C = R_T =$ 2,000 fish each would be necessary to have a precision of ± 0.05, 90% of the time when σ_S = 0.05, detection rate is 0.40, and turbine mortality is 0.05.

DISCUSSION

Immediate Improvements in Juvenile Passage Program

Activation of the PIT-tag slide-gate at Lower Granite Dam would provide direct measures of travel time through Little Goose pool, information not currently available. Alternatively, the capture, tagging, and release activities being conducted by the SMP at Little Goose Dam could be expanded to include migrants at Lower Granite Dam. Furthermore, since fall chinook migratory characteristics are of such critical concern, and so poorly defined, they should be included in the effort. Similarly, subyearling chinook passing Rock Island Dam should be included in the ongoing tagging effort at that site. In all cases, measures of all important variables should accompany each release group.

Near- and Long-Term Improvements in Juvenile Passage Program

During the next five years, the planned installation of PIT-tag detectors and slide-gates presents improved capability for monitoring and evaluating smolt survival and migratory behavior in the Snake and Columbia Rivers. Projections are that new facilities are to be in place according to the following schedule:

Table 10. Illustrations of the number of replicate trials and release sizes per trial to have a precision of ±0.05, $(1 - \alpha) = 0.90$ of the time about the true average survival rate $(\bar{S})$ through a turbine, spill, or bypass system using the Ricker (1957) relative recovery method.

Mortality Rate	σ_S	Detection Rate	k	$R_C = R_T$	$k(2R_C)$[a]
0.05	0.05	0.20	13	1,000	26,000
		0.20	9	2,000	36,000
		0.40	9	1,000	18,000
		0.40	7	2,000	28,000
		0.60	7	1,000	14,000
		0.60	6	2,000	24,000
0.10	0.05	0.20	13	1,000	26,000
		0.20	9	2,000	36,000
		0.40	8	1,000	16,000
		0.40	7	2,000	28,000
		0.60	7	1,000	14,000
		0.60	6	2,000	24,000
0.15	0.05	0.20	12	1,000	24,000
		0.20	9	2,000	36,000
		0.40	8	1,000	16,000
		0.40	7	2,000	28,000
		0.60	6	1,000	12,000
		0.60	6	2,000	24,000
0.15	0.075	0.20	16	1,000	32,000
		0.20	12	2,000	48,000
		0.40	11	1,000	22,000
		0.40	10	2,000	40,000
		0.60	10	1,000	20,000
		0.60	9	2,000	36,000

a. Total number of PIT-tagged fish required across replicate trials.

Lower Monumental Dam	1993-94
McNary Dam	1994-95
John Day Dam	1994
Bonneville Dam	1995-96

Appropriate use of these facilities will improve the resolution of travel time information by providing views over short reaches of river, enhancing our ability to detect responses to flow fluctuations. Another benefit is that the survival estimation protocols presented by Burnham et al. (1987) can be fully exploited to estimate turbine, spill, or bypass mortality if PIT-tagged fish are rereleased to the river. This will permit direct estimation of dam effects. In conjunction with reach survival estimates, as described by Dauble et al. (1993) estimates of reservoir-related survival will also be possible over key reaches (Figures 1, 2, 3).

In addition to the facilities referred to above, new installations should be considered in Mid-Columbia. PIT-tag detectors/slide-gates could be incorporated into new bypass systems at Wanapum or Priest Rapids Dams.

Complementary Programs/Research

A number of research and evaluation programs are currently in place or planned that could either complement or directly benefit from activities described in this plan. As indicated throughout the text, the existing SMP is already executing many appropriate activities to estimate travel time and account for fish condition. However, in some cases, we propose those activities be expanded to include more species/races and reaches, and provide measures of variables for all release groups. We further suggest that numbers of fish comprising release groups, as well as the frequency of releases, should be increased to provide improved information.

Also, a number of agencies are developing a research plan to address the apparent substantive **mortality of** yearling chinook in the migration corridor enroute to Lower Granite Dam. Facets of that program will require methods to estimate smolt survival from release sites to Lower Granite Dam. The pilot reach survival study we proposed could be executed to complement their program providing benefits to both research endeavors.

Supplementation evaluation relies on comparisons of performance between outplanted and control streams. There is a major evaluation program planned in the Snake River drainage that relies, in part, on survival estimates to Lower Granite Pool. The statistical properties of those estimates are not yet defined. It would appear that reach survival estimates of the nature we propose, within the migration corridor to Lower Granite Dam, would be useful in the interpretation of supplementation survival estimates. Furthermore, demonstrating improved means to estimate survival may be useful for their direct application.

Research activities proposed herein focus on assessing the location and magnitude of key smolt responses; travel time and survival. A more comprehensive, holistic program also requires complementary investigations that focus on specific mechanisms, e.g., predation dynamics, behavioral patterns, that cause the responses we measure. Many studies, such as those being conducted by various federal and state fisheries agencies, are currently underway, but broad-scale coordination and regular scientific review and planning appear fractionated. Some activities are embraced under the SMP while other BPA-funded efforts are not. None receive the type of formal review and revision as occur annually under the US Army Corps of Engineers fish passage research program. In our view, annual review, planning, and design are not only desirable, but necessary to formulate a sound integrated and responsive fish passage research effort.

Defining the Flow/Survival Relationship

The ability to confidently quantify the relationship between smolt survival and either flow or migration speed is desired by many parties. The first step toward that end is to assess the feasibility of producing sound survival estimates. Pilot investigations should proceed in 1992. Results from such efforts will direct the design and feasibility of future research. Once the estimation procedures are satisfactorily demonstrated, efforts to quantify the effects of flow can proceed. The possibilities range from general relationships between annual indices of survival and flow/migration speed to those based on more detailed survival estimates replicated within a season. In the latter scenario, isolating flow effects from other processes that change over the course of the replication period will be a key issue.

Wild and Hatchery Fish Responses

It is desirable to distinguish between wild and hatchery populations. System-wide fin-clipping of hatchery steelhead enables such evaluations for that species and is incorporated into existing SMP evaluations. However, such distinction will not be possible for chinook stocks until all hatchery fish bear a mark that could be detected in real-time, without sacrificing the individual. Once this capability is developed, any PIT-tagging activity that intercepts active migrants will be able to generate separate estimates for hatchery and wild migrants with releases of mixed stock fish.

There is at least one possible methodology that could be implemented immediately. Every hatchery produced salmonid could be implanted with a blank magnetized CWT. The benefits with respect to smolt travel time/survival investigation is that hatchery fish would be readily distinguishable from wild salmonids when intercepted for PIT-tagging at trapsites and dams. Screening with a CWT detector would be required at each instream tagging site. Because these fish would not receive an adipose fin-clip, the absence of the fin-clip would preclude them from being sampling in the fisheries. This is to be avoided since the infusion of so many fish into the samples would overwhelm the system.

Alternatively, if sufficient numbers of wild fish PIT-tagged in natal streams survival to Lower Granite Dam, they could be rereleased and detected at other sites. Near-term evaluations should assess the integrity and utility of such estimates. Release and recovery numbers may be so small as to provide weak estimates of travel time or survival.

Opportunities to Assess Performance of Wild Fish

Snake River: 1992 Program

Travel Time:

1. Subyearling fall chinook - Intercept as they pass Lower Granite and Little Goose Dams, PIT-tag and release to the tailrace. This would complement United States Fish and Wildlife Service (USFWS) activities upstream from Lower Granite Dam and provide more direct travel time estimates over shorter reaches of river. This would be new information.

2. Yearling chinook (wild spring and summer races) - Tagged upstream from Lower Granite Dam the previous summer could be rereleased at Lower Granite Dam. yielding travel time estimates through Little Goose Reservoir. This would be new information. Observations under this year's extreme low flow conditions provide a direct basis for comparison in subsequent years. There are concerns that recovery proportions from this data set and protocol may be inadequate to yield reliable travel time estimates; this needs to be evaluated.

Snake River: Near-Term (1993-94) Program

Travel **Time: Wild Populations**

1. Subyearling fall chinook - Continue to intercept and tag at Lower Granite and Little Goose Dams. Also, rerelease tagged individuals arriving at sites equipped with slide-gates.
2. Yearling chinook (spring and summer races) - (a) Continue to rerelease pre-tagged arrivals at Lower Granite, Little Goose, and Lower Monumental Dams. Evaluate the adequacy of recovery proportions. (b) Tag composite wild population at trapsites or dams. To accomplish this, we presume all hatchery fish will be distinguishable by the presence of an external mark. Stock-specific information is not possible, only wild population at large. This will be new information.

Reach **Survival:** Wild yearling chinook - if sufficient numbers can be captured at traps or an upper dam, they could be included as a test population in the proposed pilot reach survival study. If a corresponding release group of hatchery fish were tagged at the release site, a direct hatchery versus wild fish comparison would be available.

*Snake River: **Long-Term** (1995+) Program*

Travel Time: Continue activities indicated previously for wild spring, summer, and fall chinook.

Reach Survival: Depending on results from the pilot studies, consider estimating the survival of the wild yearling chinook run at large through the reaches of the Snake River. Sample size requirements may be a concern.

*Mid-Columbia River **Near-Term** (1993-94) **Program***

Travel Time: Wild Popuiatioos

1. Sockeye - If all hatchery fish bear a distinguishing mark/tag, wild fish (unmarked) assessments are possible. Intercept and PIT-tag at dams. May be useful as a model for endangered Snake River sockeye. Stock-specific information may be acquired separately for Wenatchee and Osoyoos populations if PIT-tagging operations are properly staged.
2. Subyearling fall/summer chinook - If all hatchery fish bear a distinguishing mark/tag, wild fish (unmarked) assessments are possible. Intercept and PIT-tag at dams. Provide a basis for comparison to threatened wild falls in the Snake River.
3. Yearling spring chinook - As above.

Mid-Columbia River: Long-Term (1995 +) Program

Travel Time: Continue activities prescribed above for wild sockeye and subyearling fall/summer chinook.

Reach Survival: Depending on results of pilot survival studies, consider estimating the survival of:

a) Sockeye; run-at-large
b) Fall/summer chinook (subyearling); run-at-large
c) Spring (yearling); run-at-large

through reaches of the Mid-Columbia River. Sample size requirements will be a concern.

Lower Columbia River: Near-Term (1993-94) Program

Travel Time: Wild runs-at-large--sockeye, subyearling chinook (Snake falls; Columbia falls and summers) and yearling chinook (Snake springs/summers; Columbia springs) - Requires mass marking of all hatchery stocks. Intercept and PIT-tag at McNary Dam with recoveries at John Day Dam. Estimate travel time between those sites. Could provide direct comparison to corresponding hatchery fish if they were also simultaneously tagged and released at McNary Dam.

Lower Columbia River: Long-Term (1995 +) Program

Travel Time: Extend range from John Day Dam to Bonneville Dam for the wild runs-at-large as described for the species above.

Reach Survival: Depending on the results of the pilot studies, it may be possible to estimate the survival of some wild populations from McNary to John Day Dams.

Subyearling Chinook

To acquire reach-specific travel time estimates, migrants should be PIT-tagged in accordance with protocol II, i.e., intercept and tag fish passing dams. This will ensure that only fish exhibiting migratory behavior are considered. **As** previously noted, all suspected variables should be measured for each release group. In the case of subyearling chinook, these include not only indices of flow and smolt development, but water temperature and fish size as well, and perhaps others.

Alternatively, subyearling chinook previously tagged in rearing areas could be used **to assess flow** effects between any rereiease site and subsequent downstream detection sites. However, there are some limitations with this approach. After being tagged, groups are actively migrating, and it is not practical to acquire measurements of their biological attributes. The size and physiological disposition of individual tagged fish as they pass the upper rerelease site will not be known. Both of these biological factors are suspected to influence migratory behavior in subyearling. Furthermore, at this time so few fish are tagged upstream from Lower Granite Dam that useful travel time estimates are doubtful, and reliable survival estimates are not possible. To obtain a full complement of pertinent data, protocol II is recommended, i.e., intercept and tag migrants at dams.

Current investigations conducted by the United States Fish and Wildlife Service (Snake) and Washington Department of Fisheries (WDF) (Columbia) PIT-tag fish that are captured throughout their rearing habitat, primarily before they initiate migratory behavior. The observed migration time to the first sampling site includes both the elapsed time to initiate migration, as well as the time of the actual migration. To assess the effects of flow on migration speed, it is necessary to define the actual migration period. Presently, in order to estimate the duration of the actual migration, it is necessary to assume that all fish above a critical length are migrating and then directly estimate when particular tagged fish attained that critical length. Verification of the presumed critical length and growth rate function appears warranted, given the pivotal role of these estimates in current analyses. Protracted passage distributions not only decrease the accuracy of travel time estimates, but also make calculating representative flow conditions highly suspect.

Assessing Tagging Effects

Many ongoing and proposed activities involve capturing and tagging active migrants. There is concern that tagging a migrant en route may disrupt the normal migratory behavior. We suggest this be evaluated. One means to accomplish this could be to compare travel times of such fish against PIT-tagged fish that were previously captured upstream and are diverted back to the river at the same site where the migrants are being collected for tagging. Another means to assess effects is to subject tagged and untagged counterparts to a performance test, e.g., swimming stamina test.

Depending on the outcome, it may be necessary to hold protocol II fish for some prescribed recovery period prior to release. Another means to assess tag effects may be to compare performance with freeze-branded counterparts.

Reservoir Drawdown

Some reservoir drawdown strategies being considered in the Snake River will make many of this plan's activities impossible to execute. Any configuration that disables existing collection systems will eliminate PIT-tag detection. This is a major consideration in terms of the long-term evaluation capabilities.

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